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Determining year of death and nature of stand recovery using a time series analysis of remotely sensed data

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Project Significance

The analysis of multiyear satellite imagery (Fig. 1) can enhance the detection of forest disturbance events such as mountain pine beetle attack. By assessing changes in reflectance, or a derived metric, over time critical information needs associated with stand mortality can be explored. This includes quantifying the area of infestation at the landscape scale and establishing the timing of stand decline – essential information for a range of post-beetle management activities such as the estimation of timber shelf life and schedule of salvage harvesting, timber supply analysis and fire suppression.

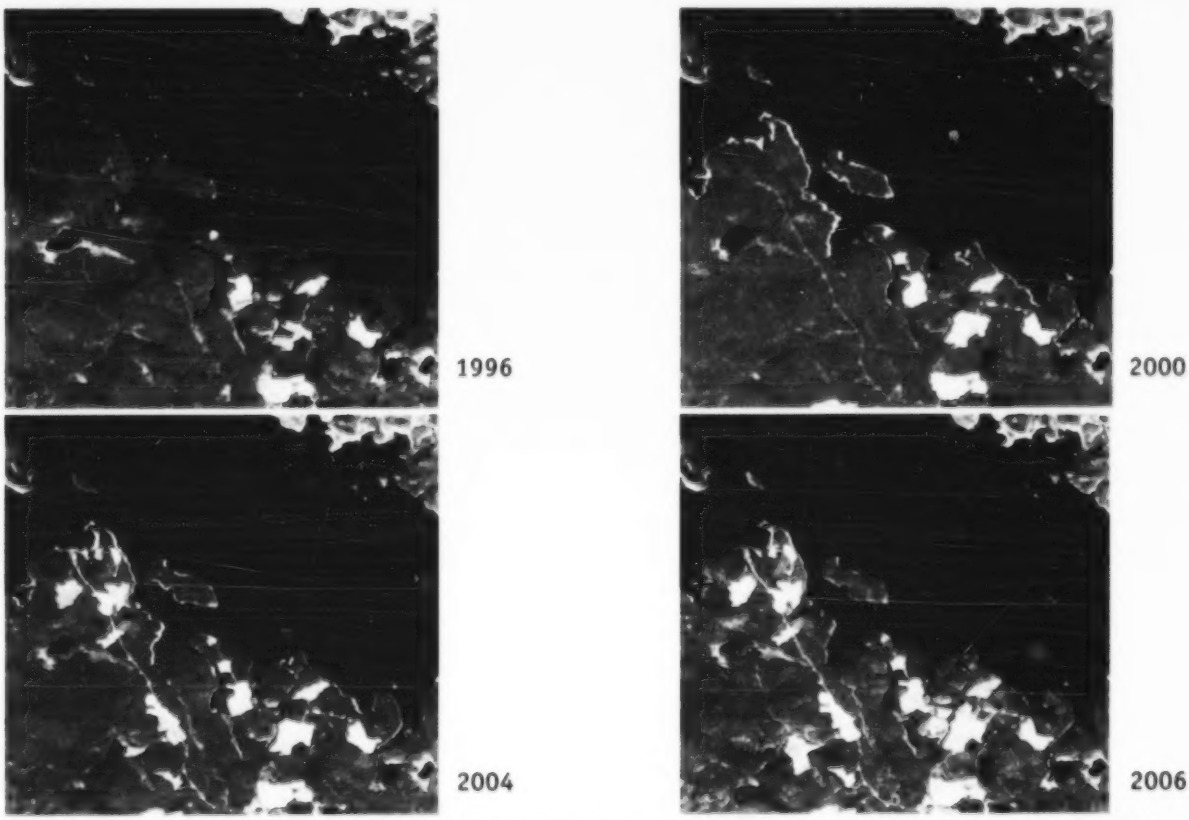

Figure 1. Illustration of mountain pine beetle attack for a subset of Morice, British Columbia, Canada (Note: Bands 5, 4 and 3 (RGB) were used from Landsat-5 TM imagery).

Overview

This report presents a procedure for characterizing beetle attack from multiyear Landsat Thematic Mapper (TM) satellite imagery. This includes a step-by-step summary of the actions needed to pre-process and then classify beetle attack (Figure 2).

STEP 1: IMAGE ACQUISITION

An important component of change detection work is to maximize the spectral change associated with beetle attack while minimizing the spectral variability from unrelated factors. Selecting similar image dates between years is preferable as it reduces potential seasonality effects. For the mountain pine beetle, July to September is suitable as it is the period when cumulative insect damage for the year is at a maximum and the sun-angle is better suited to acquiring imagery in British Columbia. In years when imagery is not available, errors of omission may result as disturbance events may be missed.

STEP 2a: IMAGE-TO-IMAGE REGISTRATION

Image-to-image geometric registration is crucial to ensure pixels from different images correspond to the same geographic location. This involves selecting a series of common "ground control points" between a base image and the images to be co-registered. Resampling used a nearest-neighbour 2nd degree polynomial transformation.

STEP 2b: ATMOSPHERIC CORRECTION

To convert digital numbers (DNs) into units of reflectance and also remove noise due to atmospheric scattering effects, a correction is required. This involves a series of transformations that both radiometrically calibrates the imagery and corrects for atmospheric scattering effects (Chavez 1996). Input data that is needed to run this correction includes the earth-sun distance and sun elevation angle at the time of image acquisition, as well as the minimum digital number for each band. Alternatively, the imagery could be radiometrically calibrated to top-of-atmosphere reflectance (see Markham & Barker 1986) and then a different atmospheric correction applied (e.g., dark object).

STEP 2c: IMAGE NORMALIZATION

Different atmospheric conditions, solar angle, and sensor characteristics are likely to limit the ability to characterize spectral change due to mountain pine beetle attack (Chen et al. 2005). As a result, the next critical step involves radiometric normalization of images to ensure that changes in spectral reflectance between years correspond to meaningful physiological events. This process essentially involves locating spectrally invariant pixels between a common base image and the image(s) to be normalized, and using these points to develop band-wise regression equations

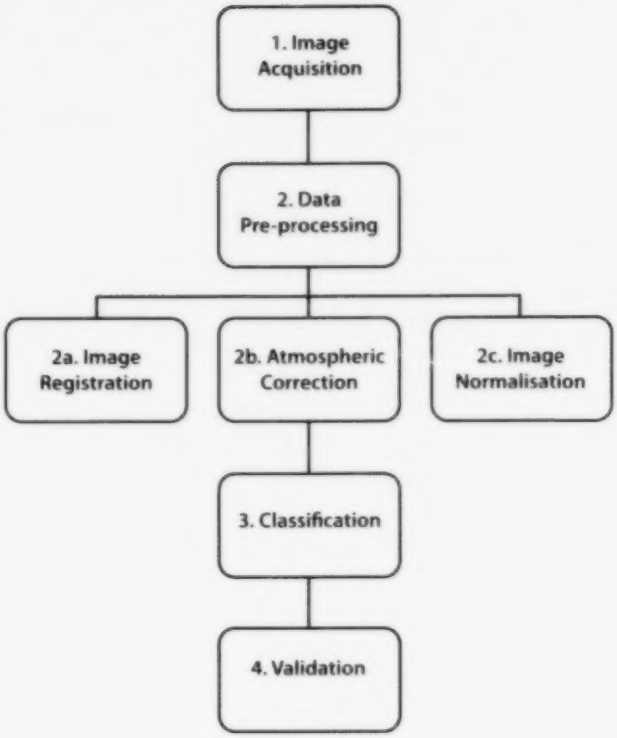

Figure 2. Flowchart of processing steps listed in sequential order.

for relative normalization. Identifying invariant pixels may be done manually or using a more automated and statistical approach such as the Multivariate Alteration Detection (MAD) algorithm (Canty et al. 2004; Schroeder et al. 2006) which utilizes canonical correlation analysis to locate invariant pixels.

STEP 3: CLASSIFICATION

Metrics and data transformations based on multiple bands are generally considered more accurate to detect disturbance events than individual band reflectance values. This is because metrics can combine information from different parts of the electromagnetic spectral to highlight changes in leaf physiology and structure caused by insect attack. The Normalized Difference Moisture Index (NDMI, Eq. 1) was used in this study due to its proven sensitivity to quantify forest disturbance events (Jin & Sader 2005; Wilson & Sader 2002).

$$NDMI = \frac{TM\ band\ 4\ (NIR) - TM\ band\ 5\ (MIR)}{TM\ band\ 4\ (NIR) + TM\ band\ 5\ (MIR)}$$

Figure 3 illustrates the classification of a forest disturbance event was achieved using a set of decision rules that evaluate the magnitude of NDMI change over time (for alternative approaches see Coppin et al. 2004). This requires training data of attack and non-attack forest along with knowledge of the physiological behaviour of beetle infested forest stands (Goodwin et al. 2008).

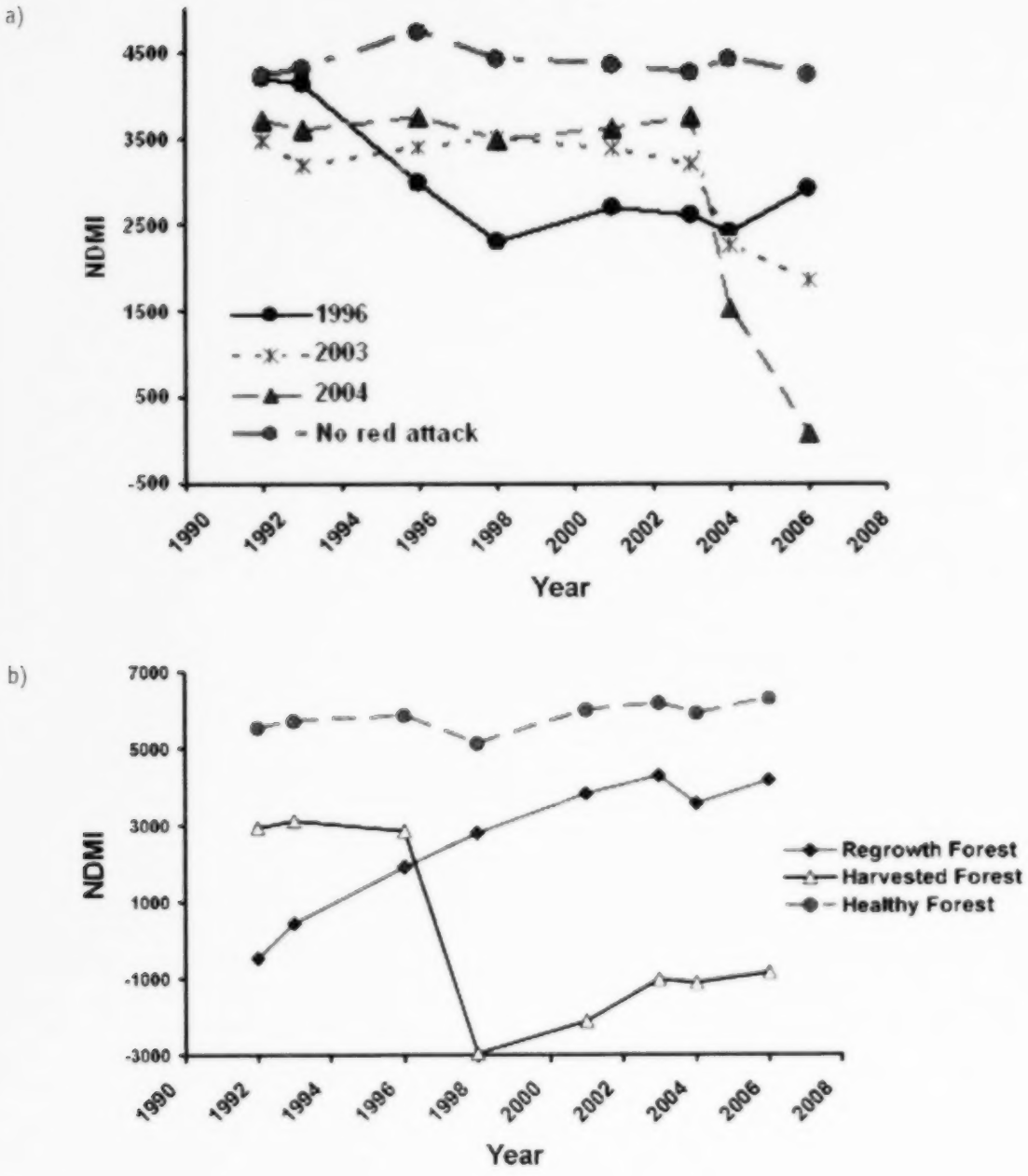

Figure 3. Illustration of disturbance events: (a) mountain pine beetle, and (b) harvest and regrowth.

STEP 4: VALIDATION OF RESULTS

To accurately characterise mountain pine beetle dynamics and link spectral changes to field data, it is advantageous to have pre-, during- and post-infestation monitoring data. Given the expensive and time-consuming nature of field data collection however, it might be worthwhile to examine the history of image acquisition success (i.e., < 20% cloud cover) prior to field plot placement, as this can provide an indication of the difficulty in acquiring imagery due to cloud cover (see White et al. 2007).

Summary

This note provides an overview of the key steps required to pre-process and extract information on mountain pine beetle dynamics using multiyear satellite data. Assuming annual cloud-free imagery is available, this approach can be used not only to classify the location(s) and area of insect attack, but also characterize its timing across forested landscapes.

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